MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2019/2020

EME3206 – CONTROL ENGINEERING
(ME)

13 MARCH 2020
9:00 a.m – 11:00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages including cover page with 5 Questions and 1 appendix.

2. Attempt **FOUR** out of **FIVE** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) The open loop transfer function of a unity feedback system with unit step input is given as

$$G(s)=\frac{1}{(s^2+s)}$$

Determine type and order of the system, natural frequency, damping ratio, peak time and maximum overshoot of the system.

[10 marks]

(b) A mechanical system is governed by the initial value problem

$$y''(t)-y'(t)=f(t)$$

where

$$f(t)=\begin{cases} e^{-t}; & 0\le t<1 \\ 0; & t\ge 1 \end{cases}$$

subjected to initial conditions $y(0)=y'(0)=0$. Find the response $y(t)$ of the system.

[15 marks]

Continued ....

Question 2

(a) The system illustrated in Figure Q2(a) is a unity feedback control system with minor feedback loop (output derivative feedback).

(i) If derivative feedback is absent ($a = 0$) and $K = 8$, determine the damping ratio and natural frequency. Also determine the steady-state error resulting from a unit-ramp input.

[6 marks]

(ii) Determine the K and a such that the steady-state error of the system with a unit-ramp input is the same value as in part (a) (i), but the damping ratio is increased to 0.7.

[7 marks]

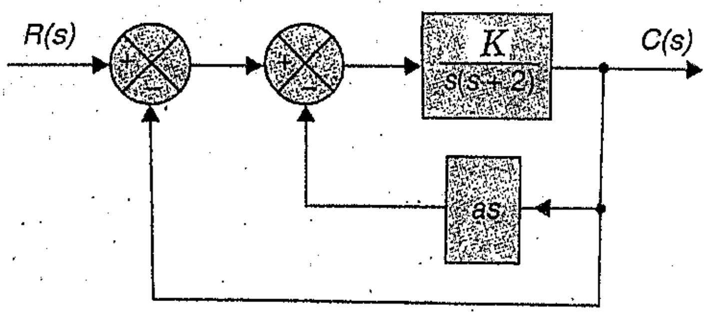

Figure Q2(a)

(b) Derive the differential equations and with initial conditions are zero obtain the transfer function relating input θ_i to output θ_o for the drive system in Figure Q2(b). The torsional spring is due to the long shaft and damping effects are due to the coupling between bearing and shaft.

[12 marks]

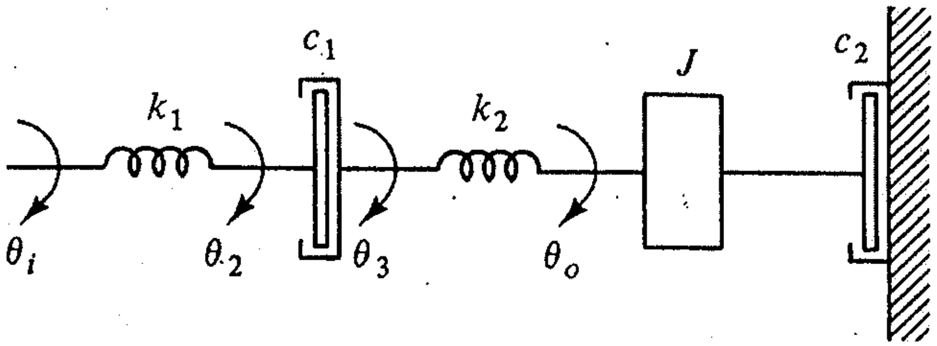

Figure Q2(b)

Continued ....

Question 3

(a) The block diagram of a control system is shown in Figure Q3(a). The $R(s)$ and $C(s)$ in the diagram are input and output of the system, respectively. Find the transfer function $C(s)/R(s)$ of the system by using block diagram reduction method.

[13 marks]

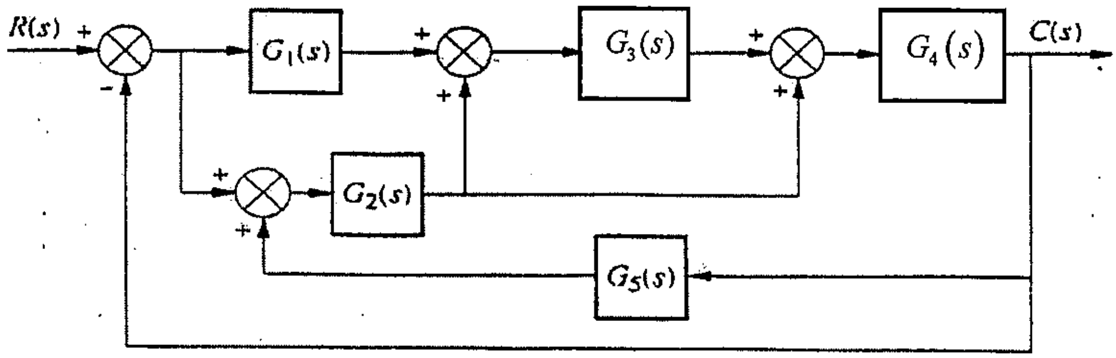

Figure Q3(a)

(b) The root loci of a unity feedback system is shown in Figure Q3(b). Obtain open-loop transfer function from the figure. Determine the gain when the closed-loop pole is located at $s = -3$ and also find the range of gain that will make the system stable.

[12 marks]

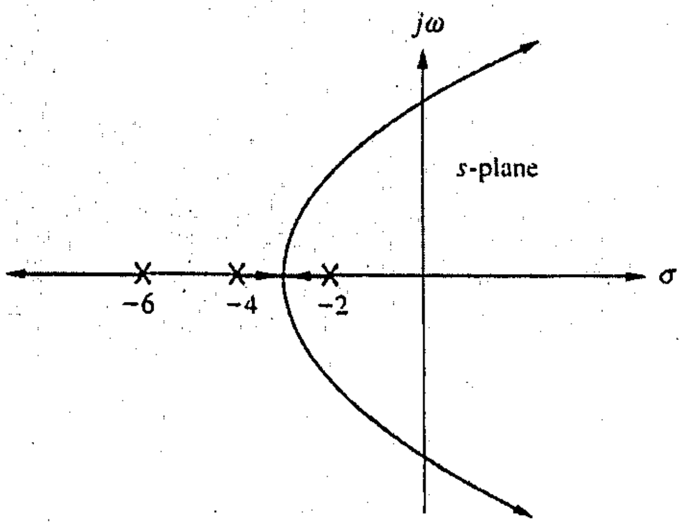

Figure Q3(b)

Continued ....

Question 4

A unity feedback control system has an open loop transfer function

$$G(s)=\frac{K(s-1)(s-2)}{s(s+1)}$$

(a) Find the frequency and gain at $j\omega$-axis crossing.

[5 marks]

(b) Find the breakaway and break-in points.

[5 marks]

(c) Sketch the root loci.

[6 marks]

(d) Find the value of K such that the system is stable and the complex closed-loop poles of the system will have a damping ratio of 0.5.

[9 marks]

Continued ....

Question 5

Figure Q5 shows a cart with a stick hinged on top of it. The cart must move such that the stick is always in the upright position. This system can also be used as a model of a space booster during the initial stage of launch. If the angular displacement θ is small, the differential equations that describe the motion of the system are given by

$$\ddot{\theta} = \alpha\theta - a_1 u$$
$$\ddot{y} = -\beta\theta + a_1 u$$

where α, β and a_1 are not equal positive constants and, u and y are input force and position of the cart, respectively.

(a) Determine the state-space representation of the system if the output of the system is $\dot{y}$ and the state vector is $\vec{x} = \begin{bmatrix} x_1 & x_2 & x_3 \end{bmatrix}^T = \begin{bmatrix} \dot{y} & \theta & \dot{\theta} \end{bmatrix}^T$.

[5 marks]

(b) Is the system controllable if we can only sense $\dot{y}$?

[5 marks]

(c) Is the system observable if we can only sense $\dot{y}$?

[5 marks]

(d) The condition that is required to design an observer for the system is the system must be observable. Show the possibility to design an observer for the system if can only sense the θ.

[5 marks]

(e) If we can use sensor to measure θ and $\dot{\theta}$, what are the matrices $[C]$ and $\{D\}$ going to be?

[5 marks]

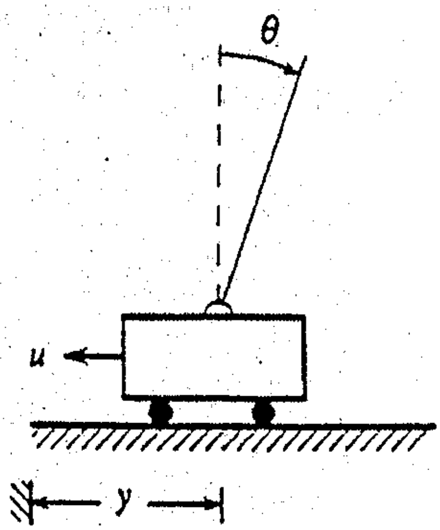

Figure Q5

Continued ....

Appendix 1: Elementary Laplace Transform

$f(t)=\mathcal{L}^{-1}\{F(s)\}$	$F(s)=\mathcal{L}\{f(t)\}$
$u(t)$	$1/(s),\ s>0$
e^{at}	$1/(s-a),\ s>a$
t^n, $n=$ positive integer	$(n!)/(s^{n+1}),\ s>0$
$\sin at$	$a/(s^2+a^2),\ s>0$
$\cos at$	$s/(s^2+a^2),\ s>0$
$e^{at}\sin bt$	$b/((s-a)^2+b^2),\ s>a$
$e^{at}\cos bt$	$(s-a)/((s-a)^2+b^2),\ s>a$
$t^n e^{at}$, $n=$ positive integer	$(n!)/((s-a)^{n+1}),\ s>a$
$u(t-t_d)$	$(e^{-t_d s})/(s),\ s>0$
$f(t-t_d)u(t-t_d)$	$e^{-t_d s}\mathcal{L}\{f(t)\}=e^{-t_d s}F(s)$
$e^{at}f(t)$	$\mathcal{L}\{f(t)\}\big\|_{s\to s-a}=F(s)\big\|_{s\to s-a}=F(s-a)$
$(f*g)(t)=\int_0^t f(t-\tau)g(\tau)d\tau$	$F(s)G(s)$
$\delta(t-t_d)$	$e^{-t_d s}$
$f^{(n)}(t)$	$s^n\mathcal{L}\{f(t)\}-s^{n-1}f(0)-s^{n-2}f'(0)-\cdots\cdots-f^{n-1}(0)$
$t^n f(t)$	$(-1)^n\dfrac{d^nF(s)}{ds^n}=(-1)^n\dfrac{d^n}{ds^n}\mathcal{L}\{f(t)\}$
$\mathcal{L}\left\{\int_0^{t_{n-1}}\cdot\cdot\int_0^{t_1}\int_0^{t}f(\tau)d\tau dt dt_1\cdot\cdot dt_{n-2}\right\}$, integrate n times	$(\mathcal{L}\{f(t)\}/s^n)=(F(s)/s^n)$
$\sinh at$	$a/(s^2-a^2),\ s>\|a\|$
$\cosh at$	$s/(s^2-a^2),\ s>\|a\|$

End of Paper.